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Reply to Comments by Burt, Klevans, and Wu

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(Received 7 March 1963)

THE comment by Burt, Klevans, and Wu[1] (BKW) on the note by Morris[2] contains a modification of the plasma dispersion expression that can be of value if it is properly qualified. BKW added a term that is necessary only when the exchange effect is important; this in no way contradicts the results presented by Morris for damping of quantized longitudinal electron oscillations in a nondegenerate plasma.

The relations given by Morris derive directly from the random phase approximation for temperatures higher than the degeneracy value. Obviously, BKW do not wish to imply that exchange is a dominating factor above the degeneracy temperature, where electrons behave as a classical gas. Therefore, clarification seems necessary.

The first three paragraphs of the original note[2] carefully define and justify the region of applicability of the dispersion relations. The reference to the k^4 order of the exchange effect is presented as a *direct quotation* from Bohm and Pines.[3] Most of the latter part of the note details plasma properties along the boundaries dictated by the initial assumptions: the region of reasonable approximation is the nondegenerate plasma, where the exchange effect is nil.

The following excerpt from the original manuscript (received 20 March 1963 by the Physics of Fluids), whence the note[2] by Morris was extracted, supports the present viewpoint:

"In 1952 Bohm and Pines[4] introduced a quantum treatment of electron behavior at metallic densities. This 'random phase approximation'[3,5–14] solved the collective Hamiltonian including long-range, linear coupling between electrons and 'plasmons.' The plasmons are quantized modes of plasma oscillations or low-momentum (long wavelength) excitations of the electron gas. The long-range electron–plasmon coupling added a quantum correction to the dispersion expression for the classical thermal plasma.

$$\omega_{qp} = \omega_{cp} + \tfrac{1}{2}\omega_p(hk^2/2m_e\omega_p)^2. \tag{4}$$

Where short-range, nonlinear effects ascend, the random phase approximation fails; therefore, in short-wavelength or low-density zero-temperature limits the "exchange" frequency shift[13,15–17] must be tacked on.

$$\Delta\omega_{qp} = -(3\omega_p/40)(k/K)^2. \tag{5}$$

While this point of strain in the Bohm and Pines presentation attracts much attention, the fact remains that a large part of plasma technology resides in the range of high temperatures. Here the random phase approximation performs adequately for low as well as high densities."[13,14]

Symbols in the preceding two paragraphs are defined there and in the reference note with the exception of K which is the wave number equivalent of electron momentum at the Fermi level.

Although the criticisms by BKW do not apply for the conditions used by Morris, the extension of the theory is gratifying; it will add to the understanding of the damping mechanism for longitudinal electron oscillations in plasmas where exchange effects must be considered.

[1] P. Burt, E. H. Klevans, and C. S. Wu, Phys. Fluids (to be published).
[2] James F. Morris, Phys. Fluids **5**, 1480 (1962).
[3] D. Bohm and D. Pines, Phys. Rev. **92**, 609 (1953).
[4] D. Bohm and D. Pines, Phys. Rev. **85**, 332 (1952).
[5] D. Pines, Phys. Rev. **92**, 625 (1953).
[6] *Solid State Physics*, edited by F. Seitz and D. Turnbull (Academic Press Inc., New York, 1955), Vol. 1.
[7] M. Gell-Mann and K. A. Brueckner, Phys. Rev. **106**, 364 (1957).
[8] K. Sawada, Phys. Rev. **106**, 372 (1957).
[9] K. Sawada, K. Brueckner, W. Fukuda, and R. Brout, Phys. Rev. **108**, 507 (1957).
[10] R. Brout, Phys. Rev. **108**, 515 (1957).
[11] J. Hubbard, Proc. Roy. Soc. (London) **A240**, 539 (1957); **A243**, 336 (1958).
[12] P. Nozieres, D. Pines, Phys. Rev. **109**, 741, 762, 1009, 1062 (1958), Nuovo Cimento **9**, 470 (1958).
[13] P. Nozieres and D. Pines, Phys. Rev. **111**, 442 (1958).
[14] F. Englert and R. Brout, Phys. Rev. **120**, 1085 (1960).
[15] V. P. Silin, Zh. Eksperim. i Teor. Fiz. **37**, 273 (1959) [English transl.: Soviet Phys.—JETP **10**, 192 (1960)].
[16] H. Kanazawa, S. Misawa, and E. Fujita, Prog. Theoret. Phys. (Kyoto) **23**, 426 (1960).
[17] O. von Roos, J. S. Zmuidzinas, Phys. Rev. **121**, 941 (1961).

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